Air Quality Monitoring in the Caroline and Sundre Area Spring and Summer, 1997 (April 22 and 23; July 21, 22 and 23)

Alberta Environmental Protection (AEP) is currently conducting an air quality monitoring program in the Caroline and Sundre area of West Central Alberta. The objectives of the program are to: (1) "map" the distribution of outdoor air quality parameter concentrations in the vicinity of the Shell Caroline plant; (2) detect the influence of elevation and topography on concentrations; and (3) identify some of the specific sulphur and hydrocarbon compounds that may be responsible for complaints. The program officially began in July, 1997 and is expected to be complete by the end of March, 1998. Additional air quality data collected in the Caroline/Sundre area in April, 1997 are also included in this report. The program was initiated in response to concerns raised by area residents through the Caroline Interrogatory Process.

The Caroline/Sundre air quality monitoring program is composed of two parts. In Part 1, the AEP Mobile Air Monitoring Laboratory (MAML) was used to conduct a preliminary assessment of air quality while in stationary and mobile modes in the Caroline/Sundre area on two days in April and three days in July of 1997. Air quality parameters monitored by the MAML included sulphur dioxide, hydrogen sulphide, total reduced sulphur, carbon monoxide, oxides of nitrogen (NO, NQ and NO_x), ozone, hydrocarbons (THC, RHC and CH_4) and particulates (TSP, PM_{10} and $PM_{2.5}$). As a result of this preliminary survey, five to ten stationary locations were selected for more intensive air quality monitoring. In Part 2, the MAML will be used to collect air quality parameter concentrations at the five to ten stationary sites determined in Part I and while in transit between sites. Additional monitoring for sulphur compounds and volatile organic compounds will be conducted at the selected stationary sites during the fall, winter and spring of 1997/98. This monitoring period coincides with the highest frequency of complaints recorded over the past two years.

The following report is a summary of the results from mobile air quality monitoring activities in the Caroline/Sundre area in the spring (April 22 and 23) and summer (July 21, 22 and 23) of 1997.

Major Findings

- Concentrations of all air quality parameters monitored in the Caroline/Sundre area were below the air quality guidelines. Maximum 1-hour average values were:
  - 25% of the 1-hour guideline for SO_2;
  - 80% of the 1-hour guideline for H_2S;
  - 71% of the 1-hour guideline for O_3;
  - 12% of the 1-hour guideline for NO_2; and
  - 7% of the 1-hour guideline for CO.
- Overall average SO_2 and H_2S concentrations were slightly higher than those measured at most other AEP stations for the same time period. The highest 1-hour average SO_2 concentrations were recorded downwind of the Shell Caroline gas plant (0.043 ppm) and near the Amoco battery (0.016 ppm). The maximum 1-hour average H_2S concentration was recorded near the Mobil Harmattan and Shell Shantz facilities (0.008 ppm).
- The highest hydrocarbon concentrations (THC and RHC) were recorded near the Amoco battery in the early morning on summer survey days. Average hydrocarbon concentrations were slightly higher than those recorded at AEP stations in small urban locations likely due to the influence of natural hydrocarbons from vegetation and fugitive hydrocarbons from industrial sources.
- O_3 values were similar to those recorded at the West Central Airshed Society background station located 30 km northwest of Hinton. O_3 concentrations are generally higher in rural areas due to natural O_3 generating processes.
- CO, NO and NO_2 values were low at all monitoring sites. Maximum CO and NO values were recorded near the Amoco battery and Amoco tank farm. The highest NO_2 values were observed near the Mobil Harmattan and Shell Shantz facilities.
- Particulate concentrations (PM_{10}) measured in the Caroline/Sundre area were much lower than those measured at AEP monitoring stations.

Sulphur Dioxide (SO_2)

Max. 1-hour Average	1-hour Guideline
SO_2 = 0.043 ppm	0.170 ppm

Sulphur dioxide (SO_2) is a colourless gas with a pungent odour. In Alberta, the major sources of SO_2 are natural gas processing

plants, oil sands facilities, and power plants. Other sources include gas plant flares, oil refineries, pulp and paper mills and fertilizer plants.

The maximum 1-hour average SO_2 concentration was measured in the in the morning on April 23 about 0.5 miles northwest of the Shell Caroline Gas Plant. The maximum value recorded at this time (0.043 ppm) is 25% of the 1-hour guideline for SO_2. Winds were from the southeast at 16 km/h when this elevated concentration was recorded. The second highest 1-hour average SO_2 value was measured in the early morning on July 23 near the Amoco Battery. The average value recorded at this location was 0.016 ppm (9% of the 1-hour guideline). Winds were from the southwest at 6 km/h when this value was recorded. Average SO_2 values at the other monitoring sites on spring and summer survey days ranged from 0.000 to 0.013 ppm. Overall average SO_2 concentrations of 0.004 and 0.003 ppm recorded on spring and summer survey days, respectively, were slightly higher than SO_2 values measured at AEP monitoring stations for the same time period.

Hydrogen Sulphide and Total Reduced Sulphur (H_2S and TRS)

Max. 1-hour Average	1-hour Guideline
H_2S = 0.008 ppm	0.010 ppm

Hydrogen sulphide (H_2S) is a colourless gas with a rotten egg odour. TRS is the total reduced sulphur contained in hydrogen sulphide, mercaptans, dimethyl sulphide, dimethyl disulphide and other sulphur compounds. Sulphur dioxide is not included in the determination of TRS. Industrial sources of H_2S and TRS include fugitive emissions (leakages) from petroleum refineries, tank farms for unrefined petroleum products, natural gas plants, petrochemical plants, oil sands plants, sewage treatment facilities, pulp and paper plants which use the kraft pulping process, and animal feedlots. Natural sources of H_2S include sulphur hot springs, sloughs, swamps and lakes.

TRS was monitored on spring survey days while TRS and H_2S were both monitored on summer survey days. The highest 1-hour average H_2S and TRS concentrations were recorded near the Mobil Harmattan and Shell Shantz facilities between 8:40 and 9:40 p.m. on July 21. Winds were from the southeast at 16 km/h during this time period. The 1-hour average H_2S value recorded at this time (0.008 ppm) was 80% of the guideline. Average H_2S and TRS concentrations ranged from 0.000 to 0.004 ppm at the remaining monitoring locations on spring and summer survey days. Overall average TRS and H_2S values on spring and summer survey days were 0.001 ppm, slightly higher than average concentrations at other AEP monitoring stations for the same time period. Average H_2S and TRS concentrations were close to the same on all summer survey days.

Hydrocarbons (THC, RHC and CH_4)

Max. 1-hour Average	1-hour Guideline
THC = 2.6 ppm	no guideline
RHC = 0.6 ppm	no guideline
CH_4 = 2.1 ppm	no guideline

The term "total hydrocarbons" (THC) refers to a broad family of chemicals that contain carbon and hydrogen atoms. Methane (CH_4), a non-reactive hydrocarbon, is the most common hydrocarbon in the earth's atmosphere. Reactive hydrocarbons (RHC) such as alkenes, alkynes and aromatics are important because they can: (1) react with oxides of nitrogen in the presence of sunlight to form ozone; and (2) be toxic to humans, animals or vegetation. Sources of hydrocarbons include vegetation, vehicular emissions, gasoline marketing and storage tanks, petroleum and chemical industries, dry cleaning, fireplaces, natural gas combustion and aircraft traffic.

Maximum 1-hour average THC (2.6 ppm) and RHC (0.6 ppm) values were recorded near the Amoco Battery in the early morning on July 23. The second highest THC and RHC values of 2.4 and 0.4 ppm, respectively, were recorded at the same location in the morning on July 22. Winds at both times were from the south-southwest to southwest from 6 to 11 km/h. Average THC and RHC values ranged from 1.8 to 2.3 ppm and 0.0 to 0.3 ppm, respectively, at the remaining monitoring locations. Overall average RHC values were 5% and 10% of average THC values for the spring and summer survey days, respectively. Overall average THC concentrations were 2.0 ppm in the spring and 2.1 ppm in the summer. These average values are slightly higher than those recorded at AEP station located in small urban areas. Slightly higher hydrocarbon values in the Caroline/Sundre area may have been due to the influence of hydrocarbons emitted by vegetation or fugitive hydrocarbon emissions from local industries. Normal background THC concentrations are between 1.5 and 2.0 ppm.

Ozone (O_3)

Max. 1-hour Average	1-hour Guideline
0.058 ppm	0.082 ppm

Ozone in the lower atmosphere is produced by: (1) the reaction of oxides of nitrogen and volatile organic compounds in the presence of sunlight; and (2) transport of O_3 from the upper atmosphere to ground level. Ozone concentrations are generally highest in the spring and summer seasons due to natural ozone producing processes. O_3 concentrations are generally lower in urban centres due to the destruction of O_3 by nitric oxide.

Ozone concentrations followed the typical daily trend observed at other locations with maximum values in the early afternoon on summer survey days and in the late afternoon on spring survey days. The maximum 1-hour average O_3 concentration was measured about 1.5 miles southeast of the Amoco Battery in mid-afternoon on April 23. Winds were from the south-southeast at 14 km/h during this time period. Ozone concentrations in the Caroline/Sundre area were generally higher than those measured at AEP monitoring stations located in small and large urban areas. However, ozone values were consistent with those measure at the High Tower Ridge station operated by the West Central Airshed Society located about 30 km northwest of Hinton. O_3 values are higher at these rural locations due to natural ozone producing processes.

Oxides of Nitrogen (NO_2, NO, NO_x)

Max. 1-hour Average	1-hour Guideline
NO_2 = 0.025 ppm	0.210 ppm
NO = 0.047 ppm	no guideline
NO_x = 0.067 ppm	no guideline

Oxides of nitrogen (NO_x) are the sum of nitrogen dioxide (NO_2) and nitric oxide (NO). During high temperature combustion, as in the burning of natural gas, coal, oil and gasoline, atmospheric nitrogen may combine with molecular oxygen to form NO. NO is colourless, odourless and has no known toxic effects. Most NO is rapidly oxidized to form NO_2. NO_2 is a reddish-brown gas with a pungent odour.

The highest 1-hour average NO_2 value was recorded near the Shell Shantz and Mobile Harmattan facilities (afternoon of July 22) and 1.5 miles south-southwest of the Shell Caroline Gas Plant (evening of July 22). Winds were from the south-southwest at 20 km/h (afternoon of July 22) and from the south-southeast at 24 km/h (evening of July 22) when these maximum NO_2 concentrations were observed. The maximum 1-hour NO concentration was measured in the early morning on July 23 near the Amoco battery. Winds were from the southwest at 6 km/h when the maximum NO value was recorded. Overall average NO_2, NO and NO_x values were generally lower than those measured in Edmonton and Calgary and close to the same or slightly higher than those measured in Fort McMurray and Fort Saskatchewan.

Carbon Monoxide (CO)

Max. 1-hour Average	1-hour Guideline
0.9 ppm	13 ppm

Carbon monoxide is a colourless, odourless gas emitted into the atmosphere primarily by motor vehicles. Minor sources include fireplaces, industry, aircraft and natural gas combustion.

Carbon monoxide values were very low on spring and summer survey days in the Caroline/Sundre area. The maximum 1-hour average concentration of 0.9 ppm was recorded near the Amoco Battery in the afternoon of April 21. Winds were from the northwest at 3 km/h when this elevated value was recorded. The second highest CO reading (0.8 ppm) was recorded around noon on April 23 about 0.5 miles west of the Amoco tank farm. Winds at this time were from the east-southeast at 7 km/h. Overall average CO concentrations in the Caroline/Sundre area were close to those recorded in Fort Saskatchewan and Fort McMurray, and substantially lower than CO values reported in downtown Calgary for the same time period.

Particulates (TSP, PM_{10} and $PM_{2.5}$)

Max. 1-hour Average	1-hour Guideline
TSP = 20 µg/m^3	no guideline
PM_{10} = 14 µg/m^3	no guideline
$PM_{2.5}$ = 4 µg/m^3	no guideline

Air pollutants are not necessarily in a gaseous form. Tiny particles of solid material or liquid droplets, defined collectively as particulates are also present in the atmosphere. Total suspended particulates (TSP) refers to all particles up to 500 microns in diameter (a human hair is about 100 microns in diameter) and are important primarily from a nuisance perspective. Particles less than 10 microns in diameter (PM_{10}) can be inhaled into the nose and throat while particles less than 2.5 microns in diameter ($PM_{2.5}$) can penetrate into the lungs. Sources of particulates include soil dust, road dust, agricultural dust (e.g. harvest), smoke from forest fires and recreational wood burning, vehicle exhaust emissions, brake and tire wear, and industrial emissions. Smaller particles ($PM_{2.5}$) originate in the atmosphere as a result of condensation and combustion from sources such as vehicle exhaust emissions, industrial emissions and wood burning.

Particulate concentrations were measured on July 21, 22 and 23 in the Caroline/Sundre area. The maximum TSP, PM_{10} and $PM_{2.5}$ concentrations were observed near the Amoco Battery on the morning of July 22. Winds were from the south-southwest at 11 km/h during this time period. Particulate values were much lower at the remaining monitoring sites on the summer survey days (TSP ranged from 2 to 8 µg/m^3, PM_{10} ranged from 1 to 6 µg/m^3 and $PM_{2.5}$ ranged from 0 to 2 µg/m^3). Overall average particulate concentrations (PM_{10}) in the Caroline/Sundre area were much lower than those recorded at AEP monitoring stations for the same time period.

A Map of Caroline/Sundre Air Quality monitoring site can be viewed at the Special Air Quality Surveys' page at http://www.gov.ab.ca/env/air/airqual/special.html

Spring, 1997

Average Concentrations at Each Monitoring Site for the Caroline/Sundre Area Survey (ppm)

April 22, 1997

Monitoring Site	Monitoring Period	CO	O_3	THC	CH_4	RHC	SO_2	NO	NO_2	NO_x	H_2S	TRS	Temp.*	Wind dir/spd*	Cloud*
In Transit	10:27 to 11:22	0.3	0.043	1.9	1.8	0.1	0.002	0.020	0.012	0.030	n/a	0.000	9.2	n/a	n/a
In Transit	11:22 to 12:18	0.3	0.049	1.9	1.8	0.1	0.000	0.020	0.011	0.031	n/a	0.001	8.2	n/a	n/a
Site #1	12:18 to 13:21	0.5	0.052	1.8	1.8	0.1	0.002	0.011	0.007	0.018	n/a	0.004	9.2	W/8	n/a
Site #6	13:38 to 13:53	0.9	0.046	1.9	1.8	0.1	0.004	0.010	0.009	0.019	n/a	0.000	7.8	WNW/30	n/a
In Transit	13:54 to 14:04	0.3	0.046	1.9	1.8	0.1	0.000	0.000	0.005	0.006	n/a	0.000	6.8	n/a	80%
site #2	14:05 to 15:07	0.2	0.050	1.8	1.8	0.1	0.001	0.000	0.004	0.004	n/a	0.000	7.4	W/19	n/a
In Transit	15:08 to 15:35	0.2	0.052	1.8	1.8	0.1	0.001	0.000	0.002	0.002	n/a	0.000	10.6	n/a	n/a
Site #3	15:36 to 16:39	0.3	0.052	1.8	1.8	0.1	0.001	0.008	0.006	0.014	n/a	0.000	10.4	E/12	n/a
In Transit	16:40 to 16:49	0.1	0.051	1.9	1.7	0.2	0.000	0.004	0.011	0.015	n/a	0.000	10.3	n/a	n/a
Site #6	16:50 to 17:03	0.2	0.044	2.2	1.9	0.3	0.007	0.006	0.011	0.016	n/a	0.001	10.1	NE/15	n/a
In Transit	17:04 to 17:11	0.2	0.051	1.9	1.8	0.1	0.002	0.000	0.000	0.000	n/a	0.000	10.1	n/a	n/a
Site #4	17:12 to 18:19	0.2	0.053	1.9	1.8	0.1	0.000	0.004	0.003	0.008	n/a	0.001	10.1	SSW/8	30%
In Transit	18:20 to 18:34	0.3	0.050	1.9	1.8	0.2	0.000	0.019	0.010	0.029	n/a	0.000	8.7	n/a	n/a

April 23, 1997

Monitoring Site	Monitoring Period	CO	O_3	THC	CH_4	RHC	SO_2	NO	NO_2	NO_x	H_2S	TRS	Temp.*	Wind dir/spd*	Cloud*
In Transit	7:38 to 8:51	0.2	0.031	n/a	n/a	0.2	0.006	0.026	0.011	0.037	n/a	0.001	3.9	n/a	0%
Site #5a	8:52 to 9:29	0.0	0.042	2.3	1.9	0.1	0.043	0.014	0.015	0.029	n/a	0.002	6.0	SE/16	25%
Site #5b	9:36 to 10:40	0.2	0.046	2.2	1.9	0.1	0.013	0.023	0.016	0.039	n/a	0.003	9.0	n/a	n/a
In Transit	10:41 to 11:21	0.1	0.047	2.1	1.8	0.1	0.000	0.005	0.011	0.016	n/a	0.000	9.6	n/a	n/a
Site #3	11:22 to 12:06	0.8	0.050	2.1	1.8	0.1	0.001	0.018	0.018	0.036	n/a	0.001	11.9	ESE/7	50%
Site #3	12:07 to 13:13	0.3	0.055	2.1	1.8	0.1	0.000	0.002	0.008	0.010	n/a	0.001	12.3	ESE/7	n/a
Site #4	13:22 to 14:22	0.1	0.057	2.1	1.9	0.1	0.000	0.000	0.004	0.004	n/a	0.001	9.3	SSE/15	80%
Site #4	14:23 to 14:51	0.2	0.058	2.1	1.9	0.1	0.000	0.000	0.005	0.005	n/a	0.001	10.1	SSE/14	n/a
In Transit	14:52 to 15:26	0.2	0.054	2.1	1.9	0.0	0.000	0.011	0.018	0.028	n/a	0.000	10.3	n/a	n/a
Site #6	15:27 to 16:02	0.3	0.057	2.1	1.8	0.0	0.001	0.006	0.014	0.019	n/a	0.001	9.3	ESE/15	40%
Site #6	16:03 to 16:36	0.2	0.056	2.1	1.8	0.1	0.003	0.001	0.009	0.010	n/a	0.001	8.4	E/13	n/a
Site #6	16:37 to 16:53	0.1	0.056	2.0	1.8	0.0	0.000	0.000	0.006	0.006	n/a	0.000	8.7	n/a	n/a

Overall Average Concentrations on All Spring Survey Days (ppm)

Location	CO	O_3	THC	CH_4	RHC	SO_2	NO	NO_2	NO_x	H_2S	TRS
Sundre Area	0.3	0.050	2.0	1.8	0.1	0.004	0.008	0.009	0.017	no data	0.001
Calgary Downtown	0.9	0.028	2.2	no data			0.013	0.032	0.044	no data	
Calgary Industrial	0.7	0.031	2.0	no data		0.003	0.019	0.033	0.052	0.000	no data
Edmonton East	0.2	0.038	2.0	no data		0.002	0.004	0.007	0.010	0.000	no data
Fort McMurray	0.3	0.033	1.9	no data		0.005	0.002	0.004	0.005	0.000	no data
Fort Saskatchewan	0.2	0.042	1.8	no data		0.001	0.002	0.005	0.007	0.000	no data
High Tower Ridge	no data	0.058	no data								
Shell Caroline Schmiemann	no data	0.053	1.9	1.9	no data	0.002	0.001	0.001	0.001	0.000	no data
Shell Caroline Eckford	no data					0.004	no data			0.000	no data
Royal Park	no data	0.041	no data								

Maximum 1-hour Average Concentrations on All Spring Survey Days (ppm)

Location	CO	O_3	THC	CH_4	RHC	SO_2	NO	NO_2	NO_x	H_2S	TRS
Sundre Area	0.9	0.058	2.3	1.9	0.3	0.043	0.026	0.018	0.039	no data	0.004
Calgary Downtown	0.9	0.058	2.3	no data			0.026	0.018	0.039	no data	
Calgary Industrial	1.9	0.040	2.5	no data		0.000	0.082	0.057	0.133	0.000	no data
Edmonton East	1.7	0.043	2.5	no data		0.005	0.076	0.052	0.129	0.001	no data
Fort McMurray	0.3	0.046	2.3	no data		0.009	0.008	0.015	0.019	0.001	no data
Fort Saskatchewan	0.5	0.042	2.1	no data		0.012	0.005	0.007	0.011	0.000	no data
High Tower Ridge	no data	0.064	no data								
Shell Caroline Schmiemann	no data	0.059	2.2	2.2	no data	0.008	0.005	0.005	0.010	0.000	no data
Shell Caroline Eckford	no data										
Royal Park	no data	0.049	no data								

* Weather conditions are based on observations at the monitoring site. Units are temperature [°C], wind speed [km/h] and cloud cover [% of sky coverage].

** Units are PM_{10}, $PM_{2.5}$ and TSP [ug/m3].

Summer, 1997
Average Concentrations at Each Monitoring Site for the Sundre Area Survey (ppm)

July 21, 1997

Monitoring Site	Monitoring Period	CO	O_3	THC	CH_4	RHC	SO_2	NO	NO_2	NO_x	H_2S	TRS	TSP**	PM_{10}**	$PM_{2.5}$**	Temp.	Wind dir/spd*	Cloud*
In Transit	11:02 to 11:56	0.4	0.045	2.1	1.9	0.2	0.001	0.013	0.006	0.015	0.000	0.000	6	4	1	26.7	n/a	0%
Site 1	11:57 to12:59	0.7	0.056	2.1	1.9	0.1	0.001	0.002	0.015	0.017	0.003	0.003	2	2	1	26.6	SE/20	0%
In Transit	13:00 to 13:07	0.5	0.053	2.1	1.8	0.2	0.000	0.004	0.011	0.015	0.000	0.000	4	3	1	27.9	n/a	0%
Site 2	13:08 to 14:12	0.3	0.044	2.0	1.8	0.1	0.003	0.010	0.012	0.021	0.001	0.001	2	2	1	27.5	NE/22	0%
In Transit	14:13 to 14:30	0.3	0.047	1.9	1.8	0.0	0.000	0.007	0.007	0.013	0.000	0.000	2	1	0	28.3	n/a	0%
In Transit	14:46 to 15:03	0.4	0.049	1.9	1.8	0.1	0.001	0.004	0.007	0.011	0.000	0.000	3	2	1	27.7	n/a	0%
Site 3	15:04 to 16:06	0.5	0.048	2.0	1.8	0.1	0.001	0.003	0.006	0.009	0.001	0.001	5	4	1	29.6	ESE/10	0%
In Transit	16:07 to 16:32	0.3	0.050	1.9	1.8	0.1	0.000	0.001	0.002	0.003	0.000	0.000	15	9	5	26.7	S/63	0%
Site 4	16:33 to 17:34	0.6	0.050	1.9	1.8	0.1	0.000	0.003	0.002	0.004	0.000	0.000	2	2	1	25.7	SE/19	0%
In Transit	17:35 to 17:59	0.2	0.046	2.0	1.9	0.1	0.001	0.002	0.004	0.005	0.000	0.000	12	8	4	26.0	n/a	0%
Site 5	18:00 to 18:59	0.4	0.044	2.1	1.9	0.1	0.008	0.001	0.013	0.014	0.002	0.002	7	5	1	25.8	E/11	0%
Site 5	19:00 to 19:50	0.3	0.044	2.0	1.9	0.1	0.000	0.001	0.013	0.014	0.001	0.001	5	4	1	23.2	E/20	0%
In Transit	19:51 to 20:42	0.3	0.040	2.0	1.8	0.1	0.000	0.004	0.007	0.010	0.000	0.000	2	1	0	22.3	n/a	0%
Site 1	20:42 to 21:42	0.7	0.040	2.1	1.9	0.2	0.002	0.002	0.005	0.007	0.008	0.008	5	4	2	20.3	SE/16	0%
In Transit	21:42 to 22:23	0.4	0.033	2.1	1.8	0.2	0.001	0.005	0.015	0.021	0.001	0.002	8	4	1	20.3	n/a	0%

July 22, 1997

Monitoring Site	Monitoring Period	CO	O_3	THC	CH_4	RHC	SO_2	NO	NO_2	NO_x	H_2S	TRS	TSP**	PM_{10}**	$PM_{2.5}$**	Temp.	Wind dir/spd*	Cloud*
Site6	7:55 to 8:30	0.4	0.026	2.2	2.0	0.2	0.013	0.002	0.004	0.005	0.000	0.000	8	6	2	22.1	S/7	0%
Site6	8:30 to 9:14	0.3	0.033	2.4	2.1	0.4	0.004	0.006	0.010	0.013	0.000	0.000	20	14	4	22.2	SSW/11	n/a
In Transit	9:14 to 9:35	0.2	0.033	2.2	2.0	0.2	0.000	0.000	0.003	0.003	0.000	0.000	2	1	0	21.2	n/a	n/a
Site7	9:35 to 10:36	no data	0.041	no data			0.003	no data			0.000	0.000	4	3	1	22.0	E/11	70%
In Transit	10:36 to 11:06	0.2	0.045	2.0	1.9	0.1	0.000	0.001	0.002	0.004	0.000	0.000	14	11	3	23.5	n/a	n/a
Site 8	11:07 to 12:08	no data	0.049	no data			0.002	no data			0.001	0.001	1	1	0	23.5	n/a	40%
In Transit	12:09 to 12:35	0.3	0.048	2.0	1.8	0.1	0.000	0.003	0.004	0.006	0.000	0.000	2	1	0	23.2	n/a	n/a
Site 3	12:36 to 13:13	0.4	0.045	2.0	1.8	0.2	0.001	0.009	0.005	0.013	0.000	0.000	5	4	1	23.8	n/a	n/a
In Transit	13:14 to 14:14	0.5	0.045	2.0	1.8	0.2	0.001	0.008	0.004	0.011	0.000	0.000	2	2	1	23.3	n/a	n/a
Site 1	14:15 to 15:13	0.5	0.047	2.2	1.9	0.3	0.002	0.001	0.004	0.005	0.002	0.002	3	2	1	23.2	n/a	n/a
In Transit	15:14 to 15:40	0.3	0.031	2.0	1.9	0.1	0.007	0.011	0.016	0.027	0.001	0.001	1	1	0	23.0	n/a	90%
Site 1a	15:41 to 16:41	0.3	0.025	2.0	1.9	0.2	0.003	0.033	0.025	0.058	0.001	0.001	1	1	0	21.6	SSW/20	80%
In Transit	16:42 to 17:48	0.4	0.041	2.0	1.9	0.2	0.002	0.009	0.008	0.015	0.000	0.000	3	1	0	22.9	n/a	20%
Site7	17:49 to 18:52	0.3	0.025	2.2	1.9	0.3	0.002	0.042	0.025	0.067	0.001	0.001	2	2	1	16.6	SE/24	n/a

July 23, 1997

Monitoring Site	Monitoring Period	CO	O_3	THC	CH_4	RHC	SO_2	NO	NO_2	NO_x	H_2S	TRS	TSP**	PM_{10}**	$PM_{2.5}$**	Temp.	Wind dir/spd*	Cloud*
In Transit	6:37 to 6:49	0.4	0.010	2.4	2.0	0.4	0.000	0.014	0.003	0.014	0.000	0.000	no data			10.8	n/a	n/a
Site6	6:50 to 7:49	0.4	0.011	2.6	2.0	0.6	0.016	0.047	0.017	0.062	0.001	0.000	no data			14.9	SW/6	n/a
In Transit	8:36 to 9:09	0.4	0.026	2.2	1.8	0.3	0.001	0.003	0.001	0.003	0.000	0.000	no data			17.8	n/a	n/a
Site 10	9:09 to 10:09	0.4	0.027	2.2	1.9	0.3	0.012	0.003	0.003	0.006	0.000	0.000	no data			18.6	ENE/12	0%
In Transit	10:10 to 11:16	0.5	0.032	2.1	1.8	0.3	0.001	0.005	0.002	0.004	0.000	0.000	no data			21.2	n/a	n/a
Site 11	11:17 to 11:46	0.5	0.034	2.2	1.8	0.4	0.002	0.001	0.002	0.003	0.000	0.001	no data			20.4	n/a	n/a
In Transit	11:47 to 12:47	0.4	0.033	2.1	1.8	0.3	0.001	0.004	0.002	0.005	0.000	0.000	no data			21.0	n/a	n/a
In Transit	12:48 to 13:04	0.6	0.028	2.0	1.7	0.3	0.001	0.028	0.008	0.034	0.000	0.000	no data			21.9	n/a	n/a

Overall Average Concentrations on All Summer Survey Days (ppm)

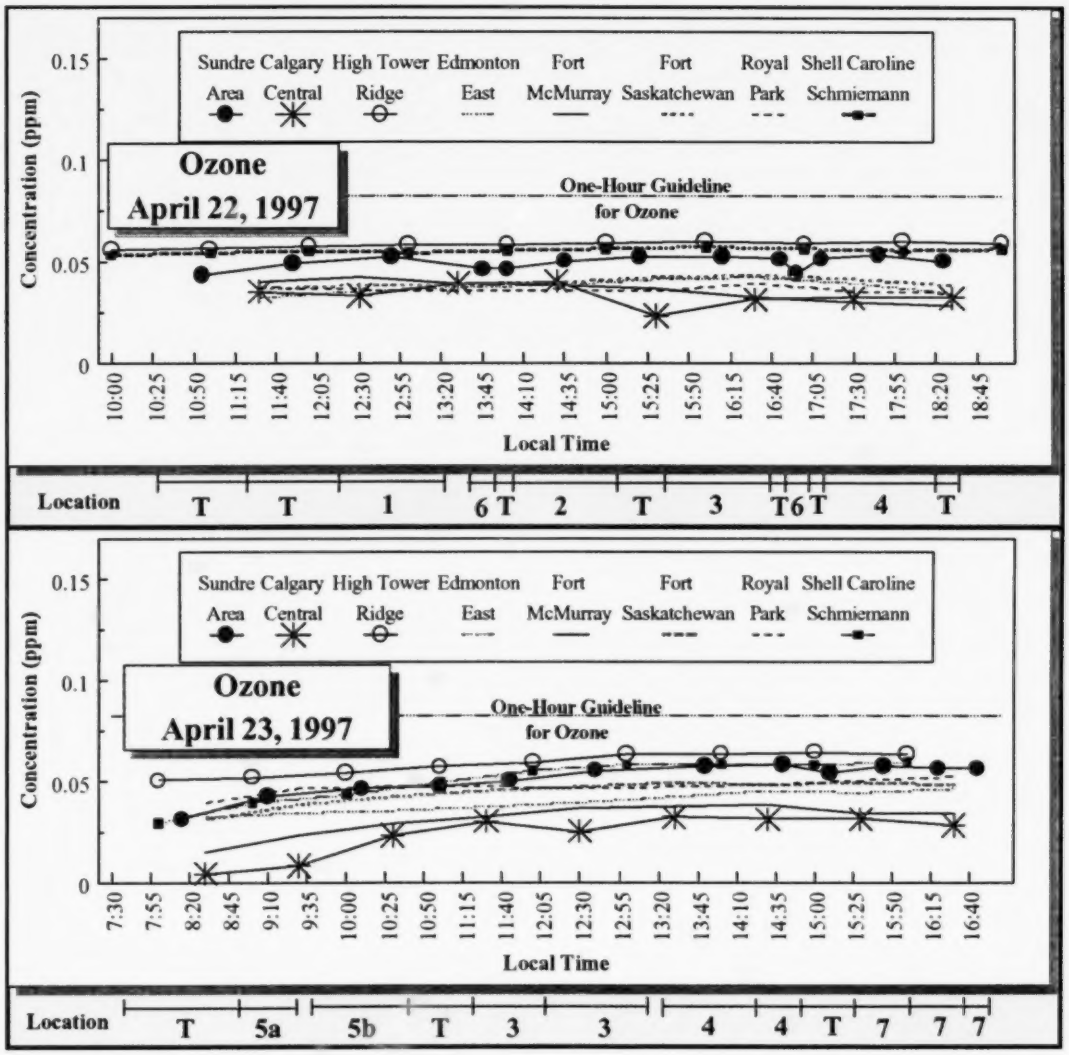
Location	CO	O_3	THC	CH_4	RHC	SO_2	NO	NO_2	NO_x	H_2S	TRS	TSP**	PM_{10}**	$PM_{2.5}$**
Sundre Area	0.4	0.038	2.1	1.9	0.2	0.003	0.008	0.008	0.015	0.001	0.001	5	4	1
Calgary Downtown	0.8	0.027	2.0	no data			0.012	0.025	0.037	no data			16	no data
Calgary Industrial	0.5	0.035	2.0	no data		0.002	0.008	0.018	0.026	0.000	no data			
Edmonton East	0.2	0.030	2.4	no data		0.002	0.009	0.008	0.016	0.000	no data			
Fort McMurray	0.2	0.023	1.7	no data		0.000	0.004	0.008	0.011	0.000	no data		8	no data
Fort Saskatchewan	0.3	0.031	1.7	no data		0.001	0.001	0.004	0.005	0.000	no data			
High Tower Ridge	no data	0.041	no data											
Shell Caroline Schmiemann	no data	0.039	2.1	1.9	no data	0.000	0.000	0.000	0.000	0.000	no data			
Shell Caroline Eckford	no data					0.002	no data			0.000	no data			
Amoco South Caroline	no data					0.000	no data			0.000	no data			
Royal Park (1996)	no data	0.030	no data				0.000	0.001	0.001	no data				

Maximum 1-hour Average Concentrations on All Summer Survey Days (ppm)

Location	CO	O_3	THC	CH_4	RHC	SO_2	NO	NO_2	NO_x	H_2S	TRS	TSP**	PM_{10}**	$PM_{2.5}$**
Sundre Area	0.7	0.056	2.6	2.1	0.6	0.016	0.047	0.025	0.067	0.008	0.008	20	14	5
Calgary Downtown	2.3	0.040	2.3	no data			0.073	0.040	0.113	0.000	no data		25	no data
Calgary Industrial	1.3	0.051	2.3	no data		0.005	0.066	0.039	0.105	0.001	no data			
Edmonton East	0.5	0.051	3.2	no data		0.011	0.051	0.022	0.071	0.002	no data			
Fort McMurray	1.4	0.040	1.8	no data		0.002	0.026	0.034	0.053	0.001	no data		21	no data
Fort Saskatchewan	0.5	0.050	2.1	no data		0.002	0.010	0.010	0.019	0.002	no data			
High Tower Ridge	no data	0.055	no data											

Spring, 1997

Average Ozone Concentrations in the Caroline/Sundre Area

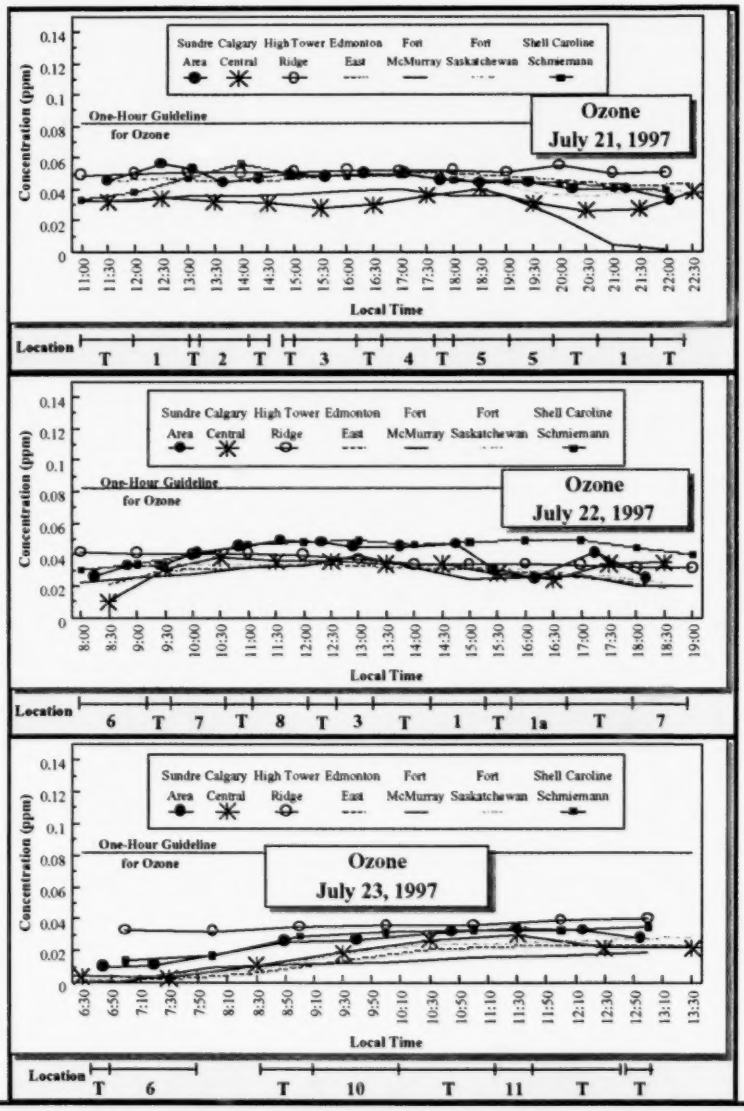


Location Legend	
Symbol	Location Description
1	Range Rd. 6-01 1.5 miles north of Hwy 587 (1 mile east-southeast of the Shell Caroline gas plant)
2	Range Rd. 5-02 0.25 miles south of Township Rd 34-00 (1.5 miles southeast of the Amoco battery)
3	Hwy 22 between Township Rd 34-00 and 34-02 (near Rangeland tank farm)
4	Township Rd 34-00 0.5 mile east of Range Rd 5-02 (1.5 miles southeast of the Amoco battery)
5a & 5b	Well site roads approx 0.5 mile northwest of the Shell Caroline gas plant
6	Range Rd 5-03 0.5 miles north of Township Rd 34-00 (near Amoco battery)

7	1 mile west-northwest of Shell Caroline gas plant at Shell meterological tower

Summer, 1997

Average Ozone Concentrations in the Caroline/Sundre Area

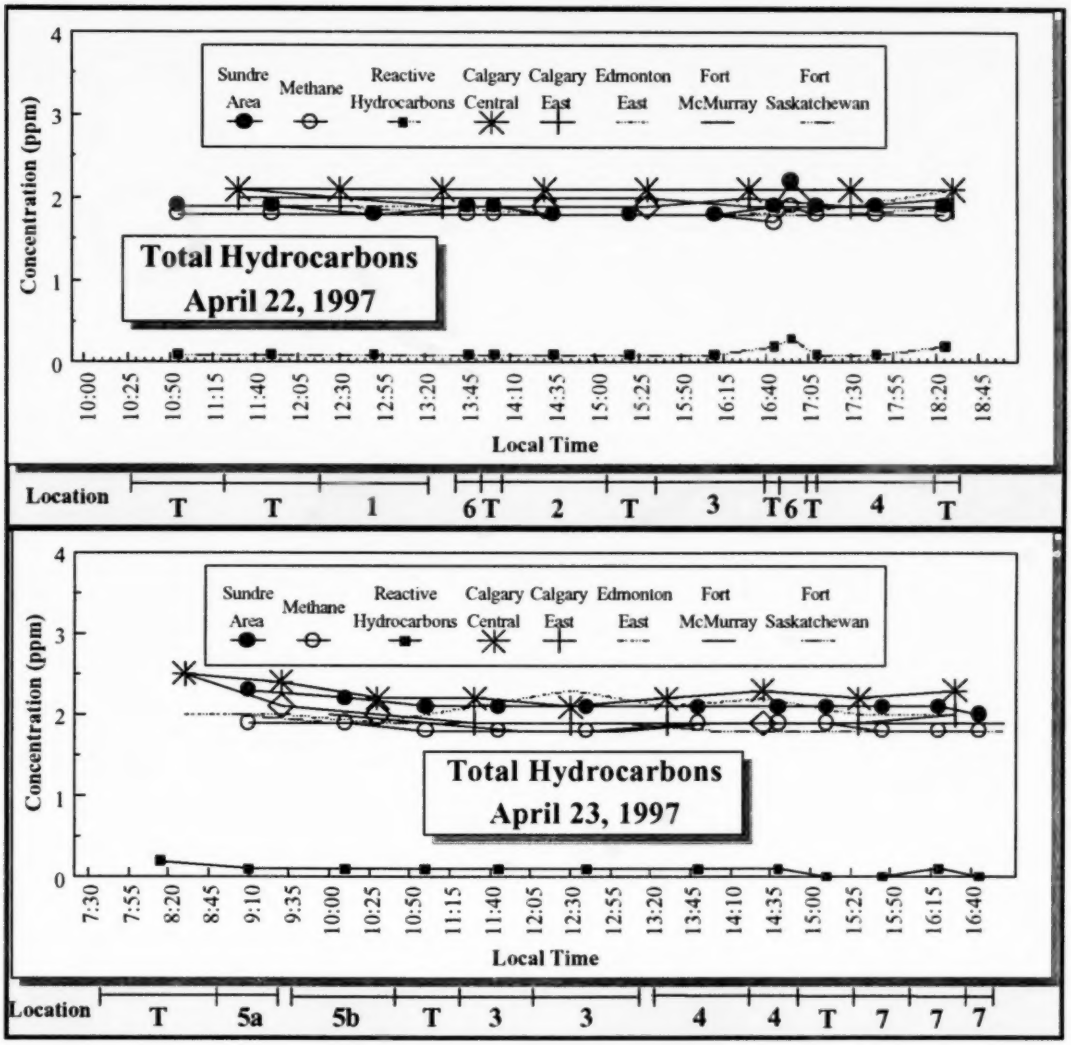


Location Legend	
Symbol	Location Description
1	Range Rd 4-02 1 mile south of Township Rd 32-00 (Bergen Rd) (between Shell Shantz and Mobil Harmattan facilities))
2	Hwy 22 and Township Rd 32-00 (Bergen Rd) (1 mile northwest of Mobil Harmattan Gas Plant)
3	Hwy 22 between Township Rd 34-00 and 34-02 (0.5 miles west of the Amoco tank farm)
4	Burnstick Lake Rd. at equivalent of Rge Rd 6-02 & Twp rd 35-02 (2.5 miles northwest of the Shell Caroline gas plant)
5	Well site roads approx 0.5 miles northwest of the Shell Caroline gas plant
6	Range Rd 5-03 0.5 miles north of Township Rd 34-00 (near Amoco Battery)
7	Township Rd 34-04(Hwy 587) 0.25 to 1.25 miles west of Rge Rd 6-01 (1.5 miles SSW of Shell Caroline gas plant)
8	Well lease Rd approx 3.5 miles SSW of Shell Caroline gas plant
9	Shell Caroline gas plant access road approx 0.5 miles ENE of plant

10	Range Rd 4-05 and Township Rd 34-02A (1 mile SSW of Amoco South Caroline gas plant)
11	Well lease Rd about 1 mile SW of Shell Caroline gas plant

Spring, 1997

Average Hydrocarbon Concentrations in the Caroline/Sundre Area

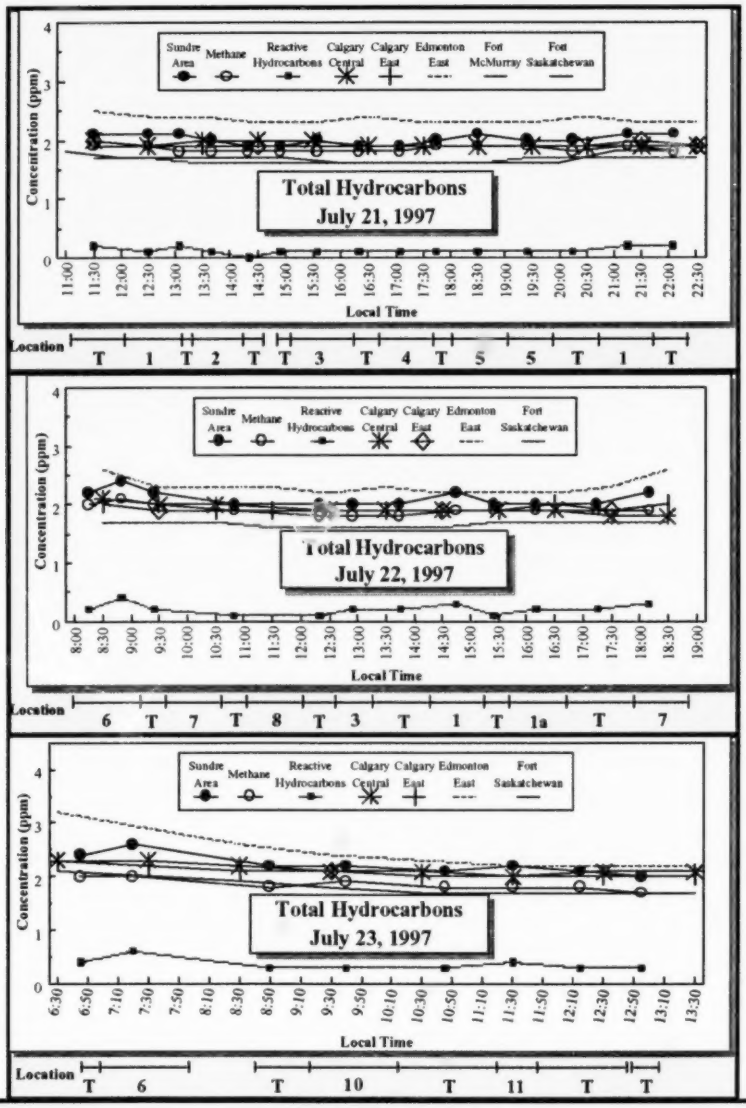


Location Legend	
Symbol	Location Description
1	Range Rd. 6-01 1.5 miles north of Hwy 587 (1 mile east-southeast of the Shell Caroline gas plant)
2	Range Rd. 5-02 0.25 miles south of Township Rd 34-00 (1.5 miles southeast of the Amoco battery)
3	Hwy 22 between Township Rd 34-00 and 34-02 (near Rangeland tank farm)
4	Township Rd 34-00 0.5 mile east of Range Rd 5-02 (1.5 miles southeast of the Amoco battery)
5a & 5b	Well site roads approx 0.5 mile northwest of the Shell Caroline gas plant
6	Range Rd 5-03 0.5 miles north of Township Rd 34-00 (near Amoco battery)

7	1 mile west-northwest of Shell Caroline gas plant at Shell meterological tower

Summer, 1997

Average Hydrocarbon Concentrations in the Caroline/Sundre Area



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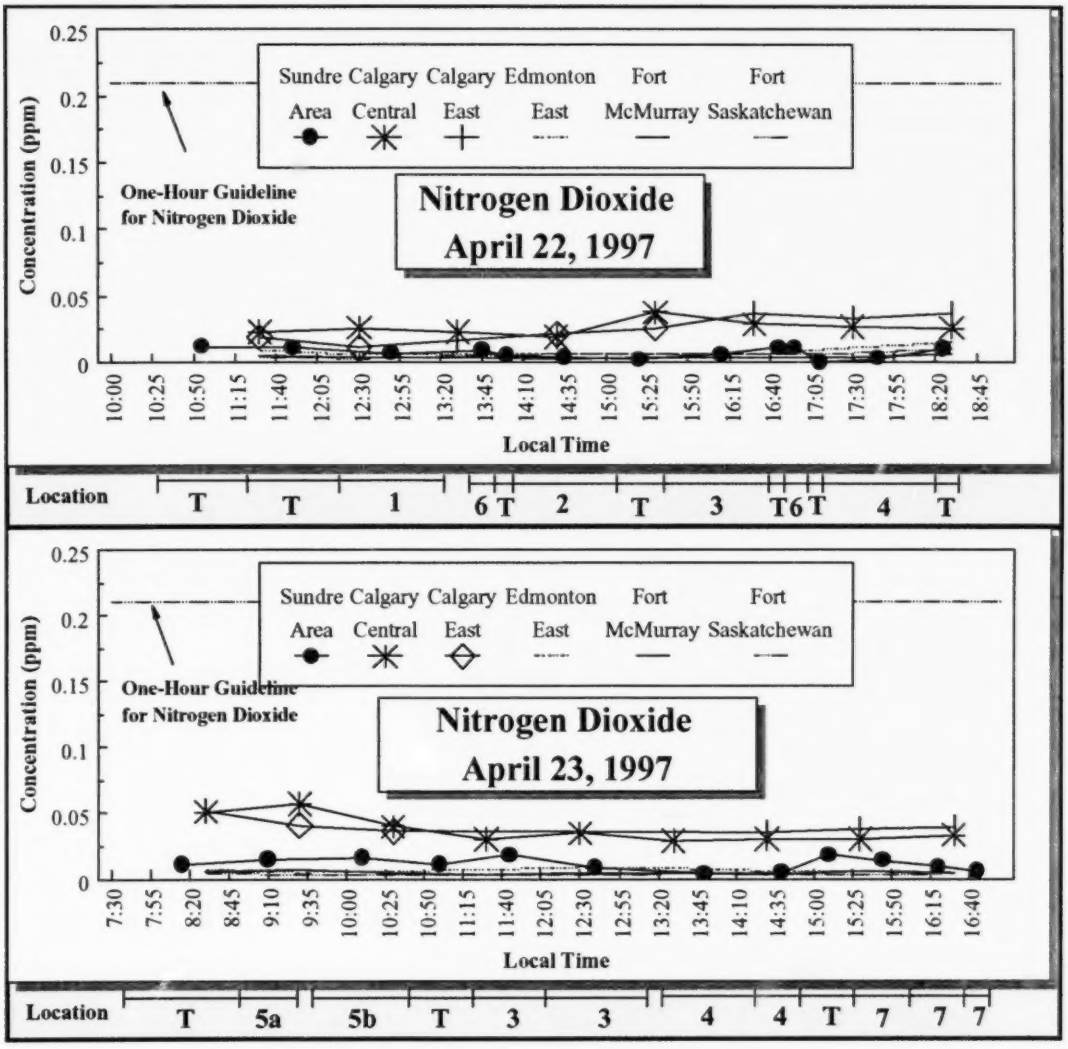
3	Hwy [illegible]tween Township Rd 34-00 and 34-02 (0.5 miles west of the Amoco tank farm)
4	Burnstick [illegible] Rd. at equivalent of Rge Rd 6-02 & Twp rd 35-02 (2.5 miles northwest of the Shell Caroline gas plant)
5	Well site roads approx 0.5 miles northwest of the Shell Caroline gas plant
6	Range Rd 5-03 0.5 miles north of Township Rd 34-00 (near Amoco Battery)
7	Township Rd 34-04(Hwy 587) 0.25 to 1.25 miles west of Rge Rd 6-01 (1.5 miles SSW of Shell Caroline gas plant)
8	Well lease Rd approx 3.5 miles SSW of Shell Caroline gas plant
9	Shell Caroline gas plant access road approx 0.5 miles ENE of plant
10	Range Rd 4-05 and Township Rd 34-02A (1 mile SSW of Amoco South Caroline gas plant)

11	Well lease Rd about 1 mile SW of Shell Caroline gas plant

Spring, 1997

Average Nitrogen Dioxide Concentrations in the Caroline/Sundre Area



Location Legend	
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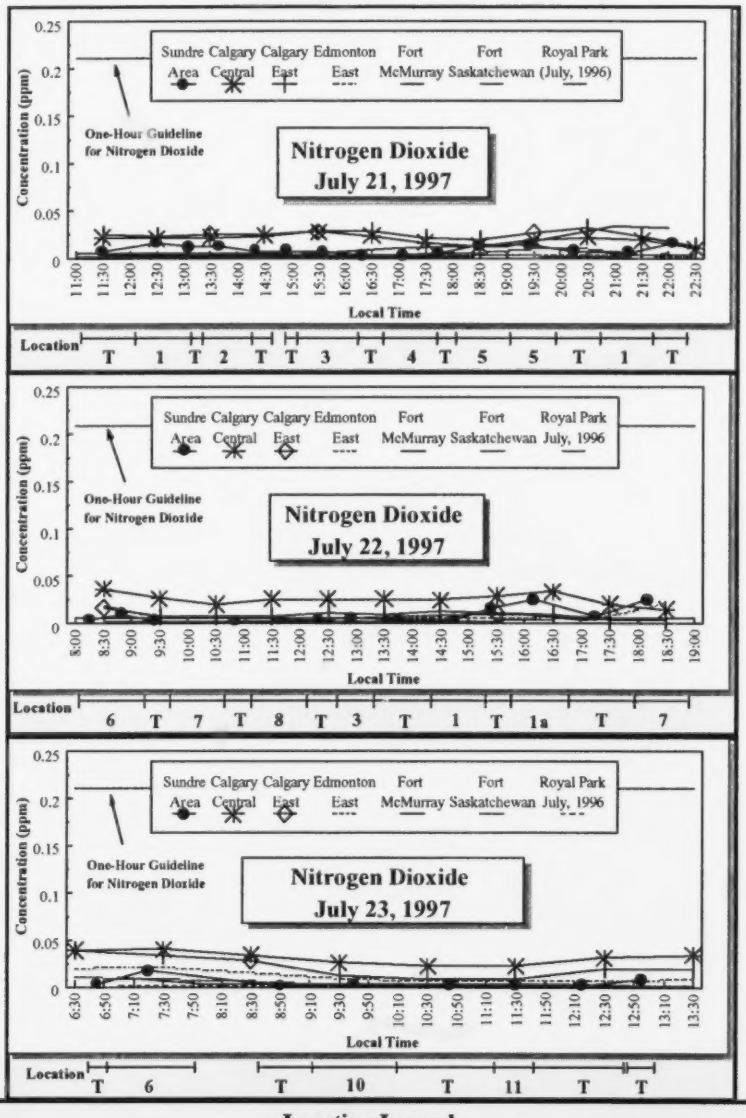
2	Range Rd. 5-02 0.25 miles south of Township Rd 34-00 (1.5 miles southeast of the Amoco battery)
3	Hwy 22 between Township Rd 34-00 and 34-02 (near Rangeland tank farm)
4	Township Rd 34-00 0.5 mile east of Range Rd 5-02 (1.5 miles southeast of the Amoco battery)
5a & 5b	Well site roads approx 0.5 mile northwest of the Shell Caroline gas plant
6	Range Rd 5-03 0.5 miles north of Township Rd 34-00 (near Amoco battery)
7	1 mile west-northwest of Shell Caroline gas plant at Shell meterological tower

Summer, 1997

Average Nitrogen Dioxide Concentrations in the Caroline/Sundre Area



Location Legend	
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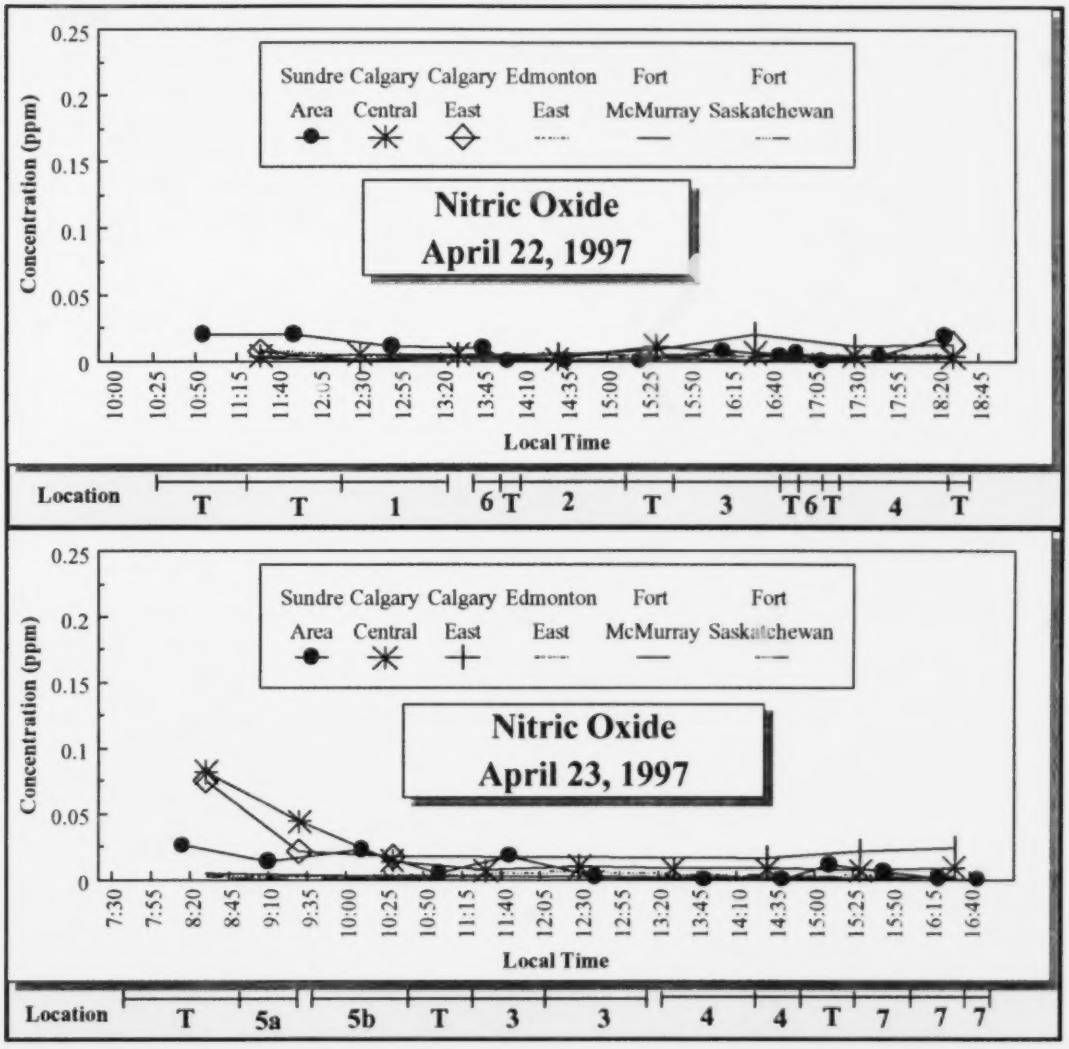
3	Hwy 22 between Township Rd 34-00 and 34-02 (0.5 miles west of the Amoco tank farm)
4	Burnstick Lake Rd. at equivalent of Rge Rd 6-02 & Twp rd 35-02 (2.5 miles northwest of the Shell Caroline gas plant)
5	Well site roads approx 0.5 miles northwest of the Shell Caroline gas plant
6	Range Rd 5-03 0.5 miles north of Township Rd 34-00 (near Amoco Battery)
7	Township Rd 34-04(Hwy 587) 0.25 to 1.25 miles west of Rge Rd 6-01 (1.5 miles SSW of Shell Caroline gas plant)
8	Well lease Rd approx 3.5 miles SSW of Shell Caroline gas plant
9	Shell Caroline gas plant access road approx 0.5 miles ENE of plant
10	Range Rd 4-05 and Township Rd 34-02A (1 mile SSW of Amoco South Caroline gas plant)
11	Well lease Rd about 1 mile SW of Shell Caroline gas plant

Spring, 1997

Average Nitric Oxide Concentrations in the Caroline/Sundre Area



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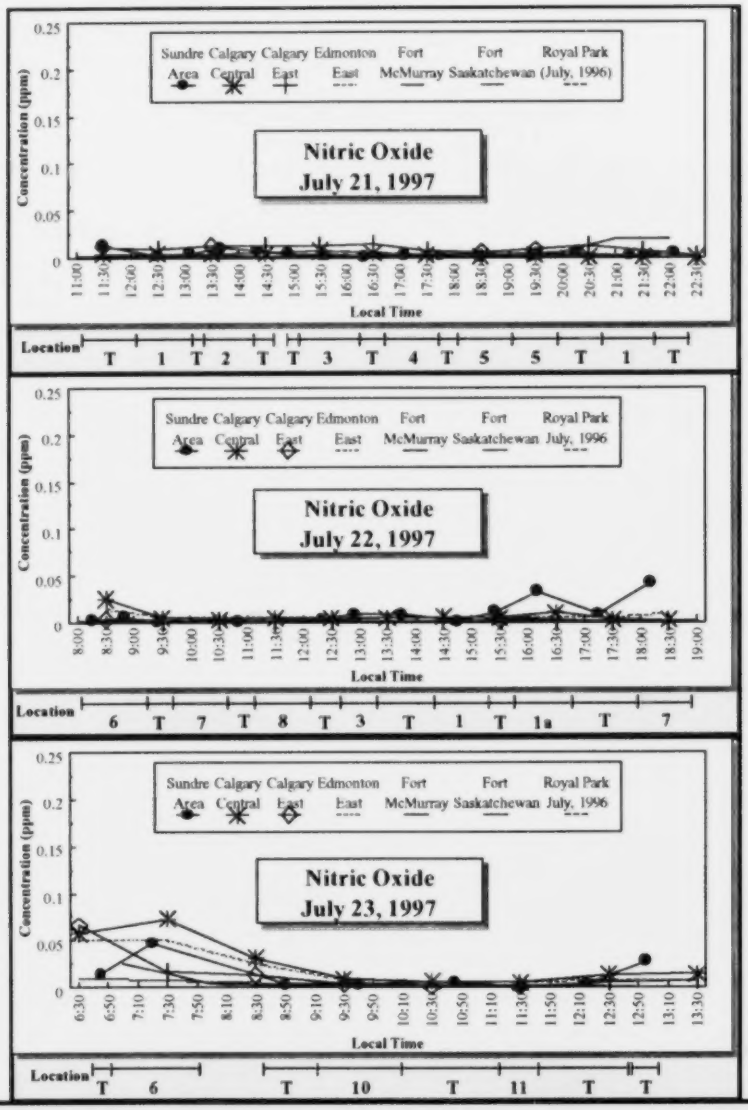
4	Township Rd 34-00 0.5 mile east of Range Rd 5-02 (1.5 miles southeast of the Amoco battery)
5a & 5b	Well site roads approx 0.5 mile northwest of the Shell Caroline gas plant
6	Range Rd 5-03 0.5 miles north of Township Rd 34-00 (near Amoco battery)
7	1 mile west-northwest of Shell Caroline gas plant at Shell meterological tower

Summer, 1997

Average Nitric Oxide Concentrations in the Caroline/Sundre Area



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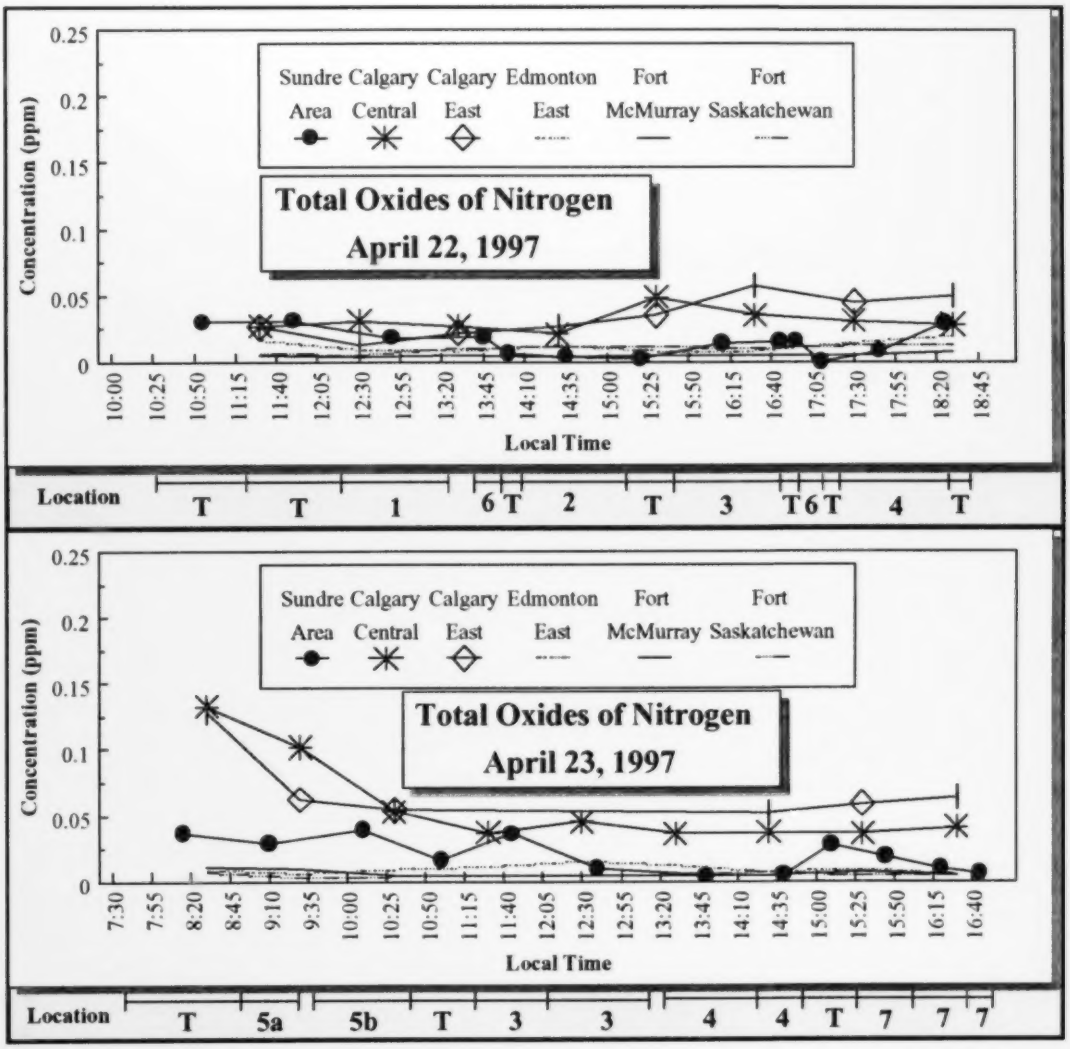
9	Shell Caroline gas plant access road approx 0.5 miles ENE of plant
10	Range Rd 4-05 and Township Rd 34-02A (1 mile SSW of Amoco South Caroline gas plant)
11	Well lease Rd about 1 mile SW of Shell Caroline gas plant

Spring, 1997

Average Total Oxides of Nitrogen Concentrations in the Caroline/Sundre Area



Location Legend	
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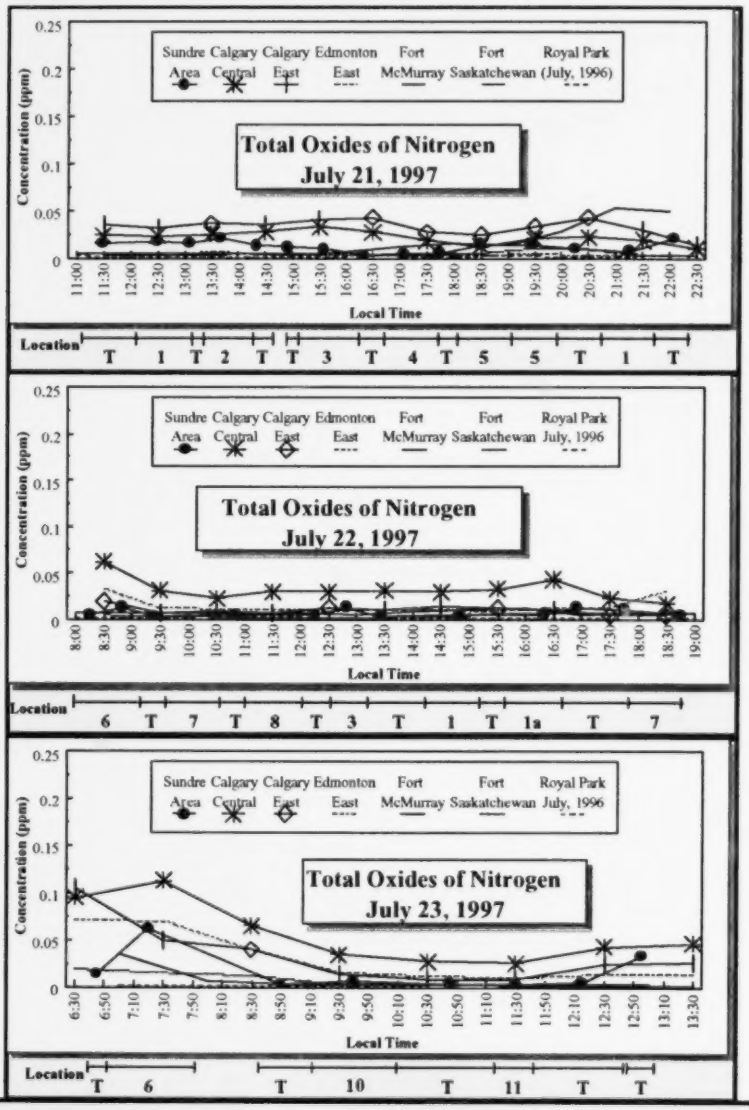
5a & 5b	Well site roads approx 0.5 mile northwest of the Shell Caroline gas plant
6	Range Rd 5-03 0.5 miles north of Township Rd 34-00 (near Amoco battery)
7	1 mile west-northwest of Shell Caroline gas plant at Shell meterological tower

Summer, 1997

Average Total Oxides of Nitrogen Concentrations in the Caroline/Sundre Area



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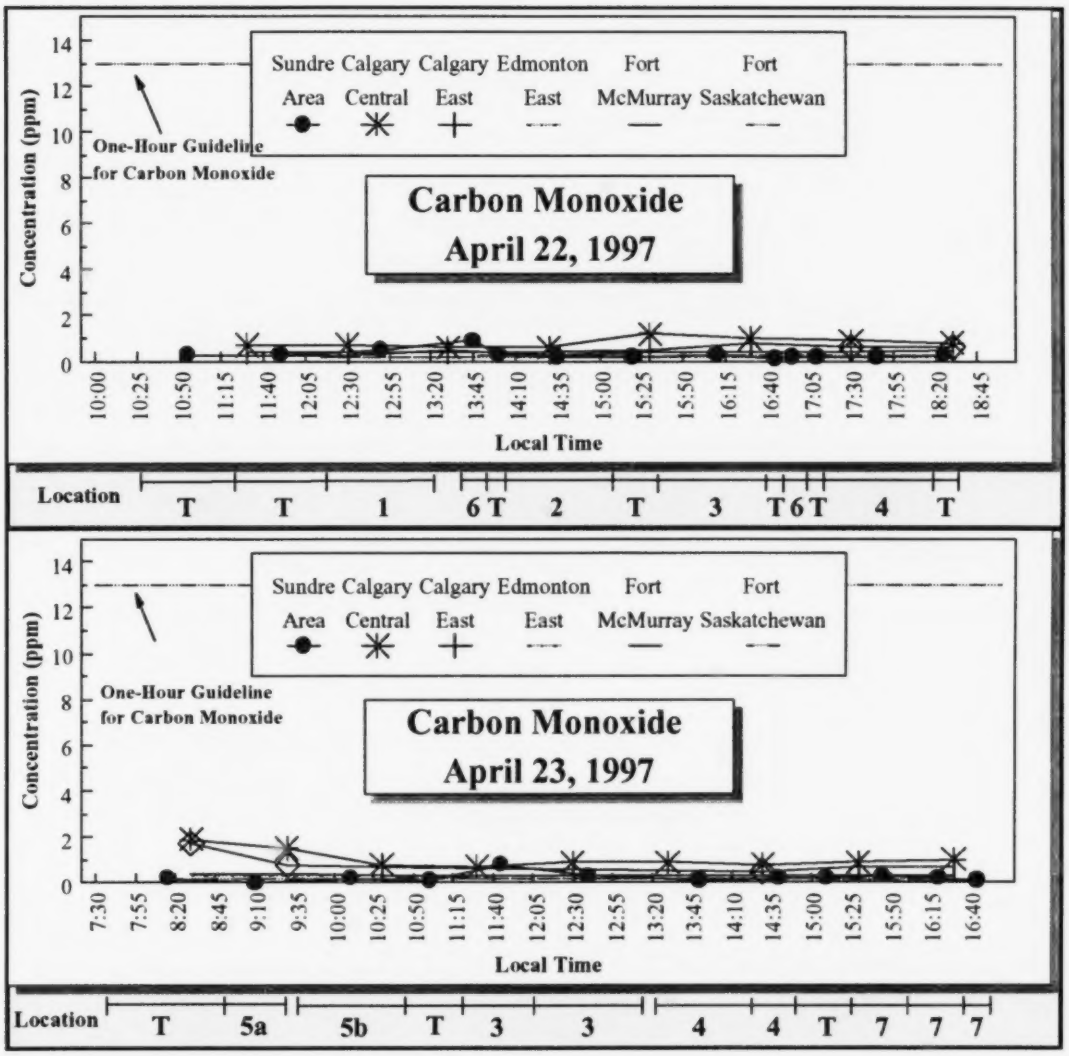
8	Well lease Rd approx 3.5 miles SSW of Shell Caroline gas plant
9	Shell Caroline gas plant access road approx 0.5 miles ENE of plant
10	Range Rd 4-05 and Township Rd 34-02A (1 mile SSW of Amoco South Caroline gas plant)
11	Well lease Rd about 1 mile SW of Shell Caroline gas plant

Spring, 1997

Average Carbon Monoxide Concentrations in the Caroline/Sundre Area



Location Legend	
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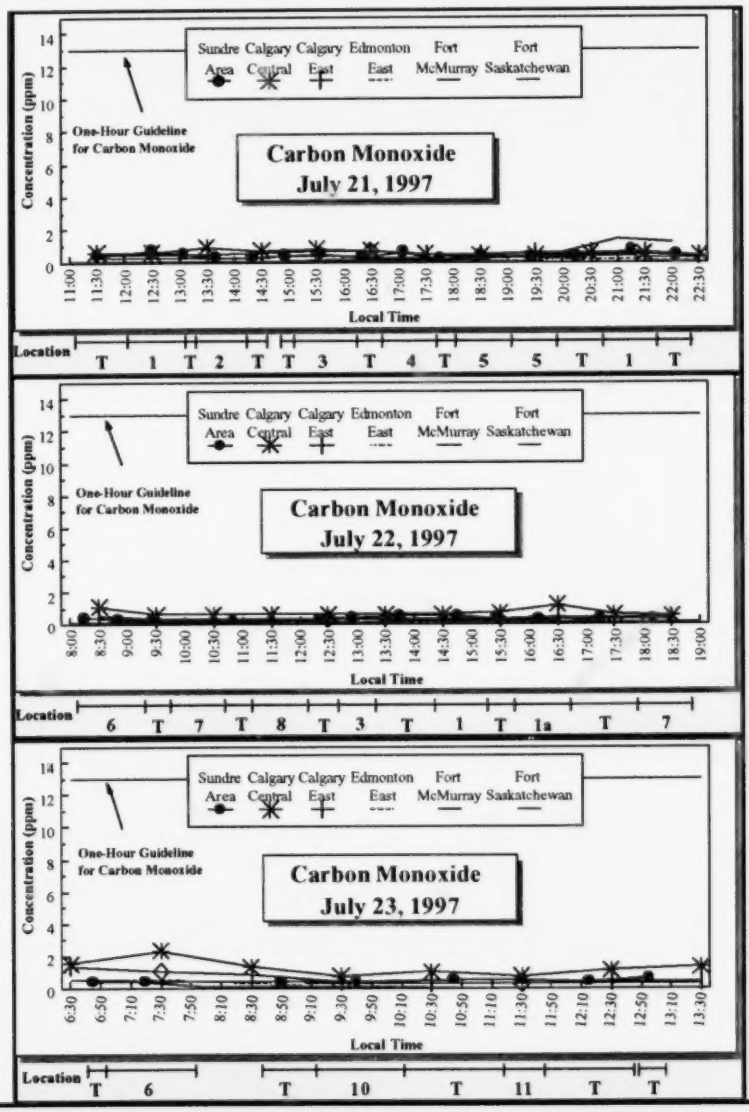
5a & 5b	Well site roads approx 0.5 mile northwest of the Shell Caroline gas plant
6	Range Rd 5-03 0.5 miles north of Township Rd 34-00 (near Amoco battery)
7	1 mile west-northwest of Shell Caroline gas plant at Shell meterological tower

Summer, 1997

Average Carbon Monoxide Concentrations in the Caroline/Sundre Area



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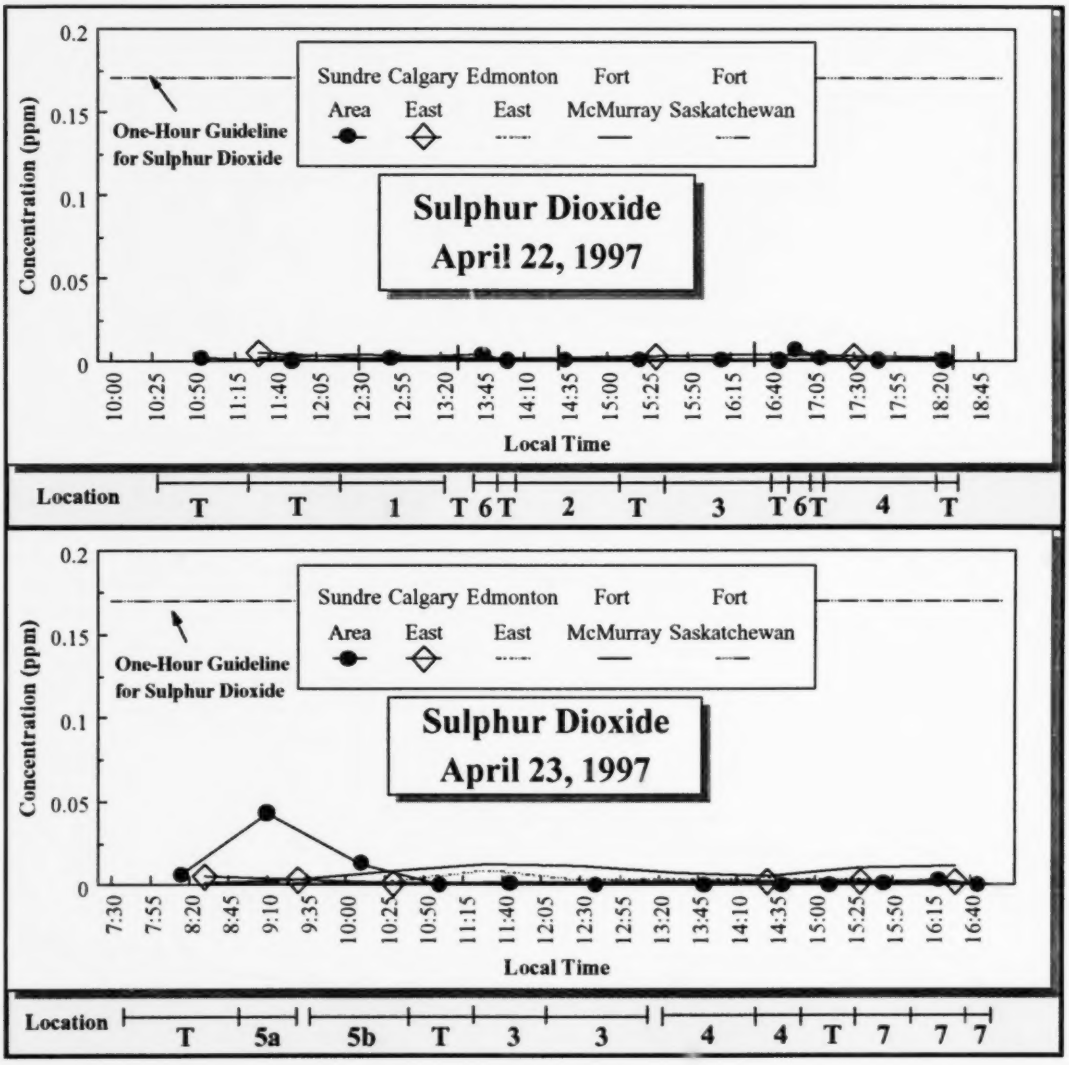
9	Shell Caroline gas plant access road approx 0.5 miles ENE of plant
10	Range Rd 4-05 and Township Rd 34-02A (1 mile SSW of Amoco South Caroline gas plant)
11	Well lease Rd about 1 mile SW of Shell Caroline gas plant

Spring, 1997

Average Sulphur Dioxide Concentrations in the Caroline/Sundre Area



Location Legend	
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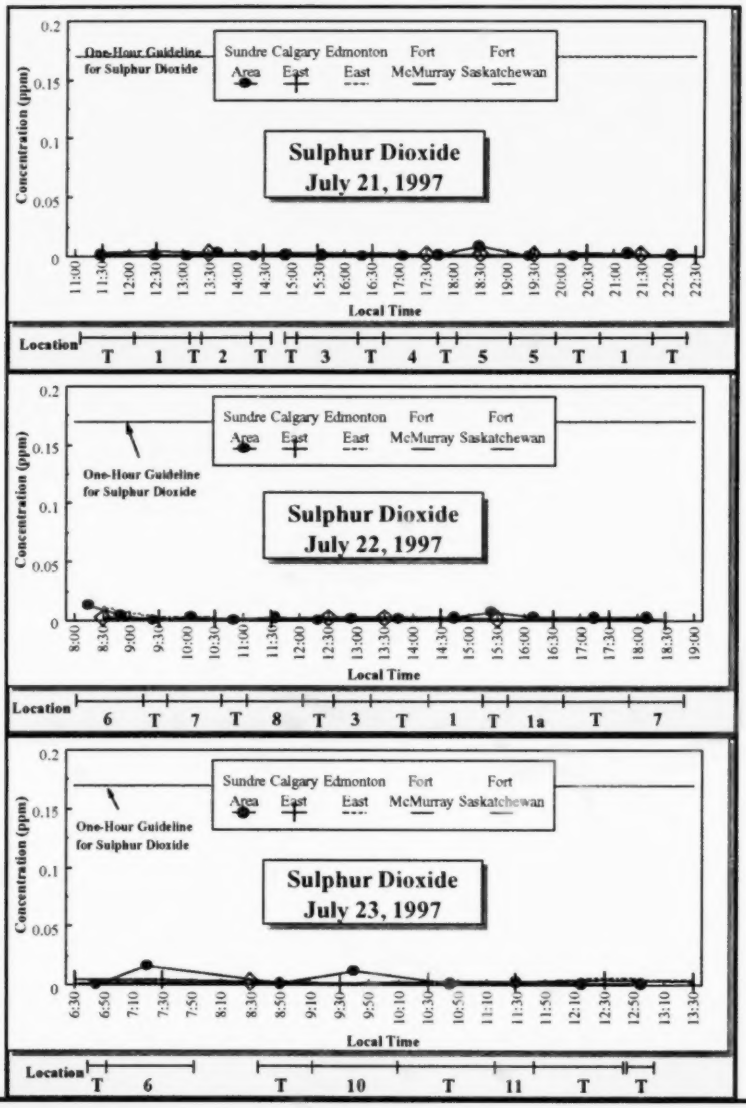
5a & 5b	Well site roads approx 0.5 mile northwest of the Shell Caroline gas plant
6	Range Rd 5-03 0.5 miles north of Township Rd 34-00 (near Amoco battery)
7	1 mile west-northwest of Shell Caroline gas plant at Shell meterological tower

Summer, 1997

Average Sulphur Dioxide Concentrations in the Caroline/Sundre Area



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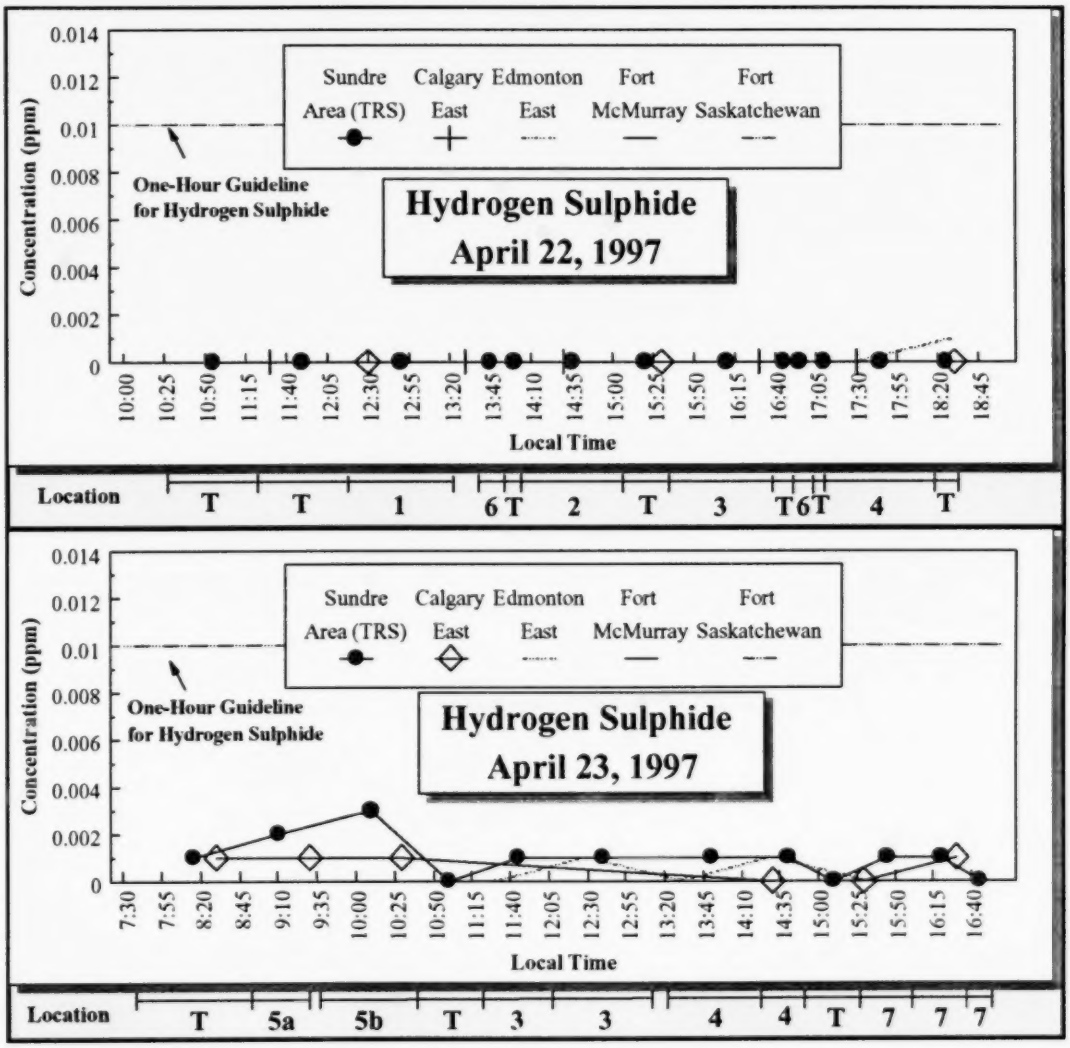
9	Shell Caroline gas plant access road approx 0.5 miles ENE of plant
10	Range Rd 4-05 and Township Rd 34-02A (1 mile SSW of Amoco South Caroline gas plant)
11	Well lease Rd about 1 mile SW of Shell Caroline gas plant

Spring, 1997

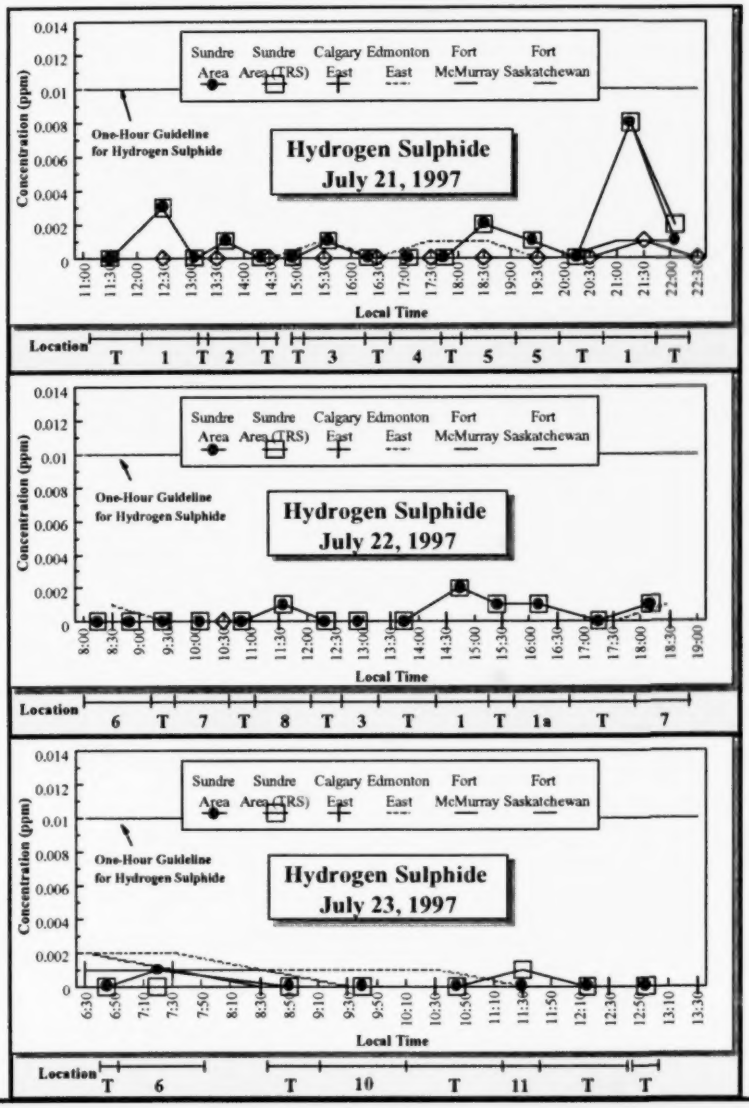
Average Total Reduced Sulphur Concentrations in the Caroline/Sundre Area



Location Legend	
Symbol	Location Description
1	Range Rd. 6-01 1.5 miles north of Hwy 587 (1 mile east-southeast of the Shell Caroline gas plant)
2	Range Rd. 5-02 0.25 miles south of Township Rd 34-00 (1.5 miles southeast of the Amoco battery)
3	Hwy 22 between Township Rd 34-00 and 34-02 (near Rangeland tank farm)
4	Township Rd 34-00 0.5 mile east of Range Rd 5-02 (1.5 miles southeast of the Amoco battery)
5a & 5b	Well site roads approx 0.5 mile northwest of the Shell Caroline gas plant
6	Range Rd 5-03 0.5 miles north of Township Rd 34-00 (near Amoco battery)
7	1 mile west-northwest of Shell Caroline gas plant at Shell meterological tower

Summer, 1997

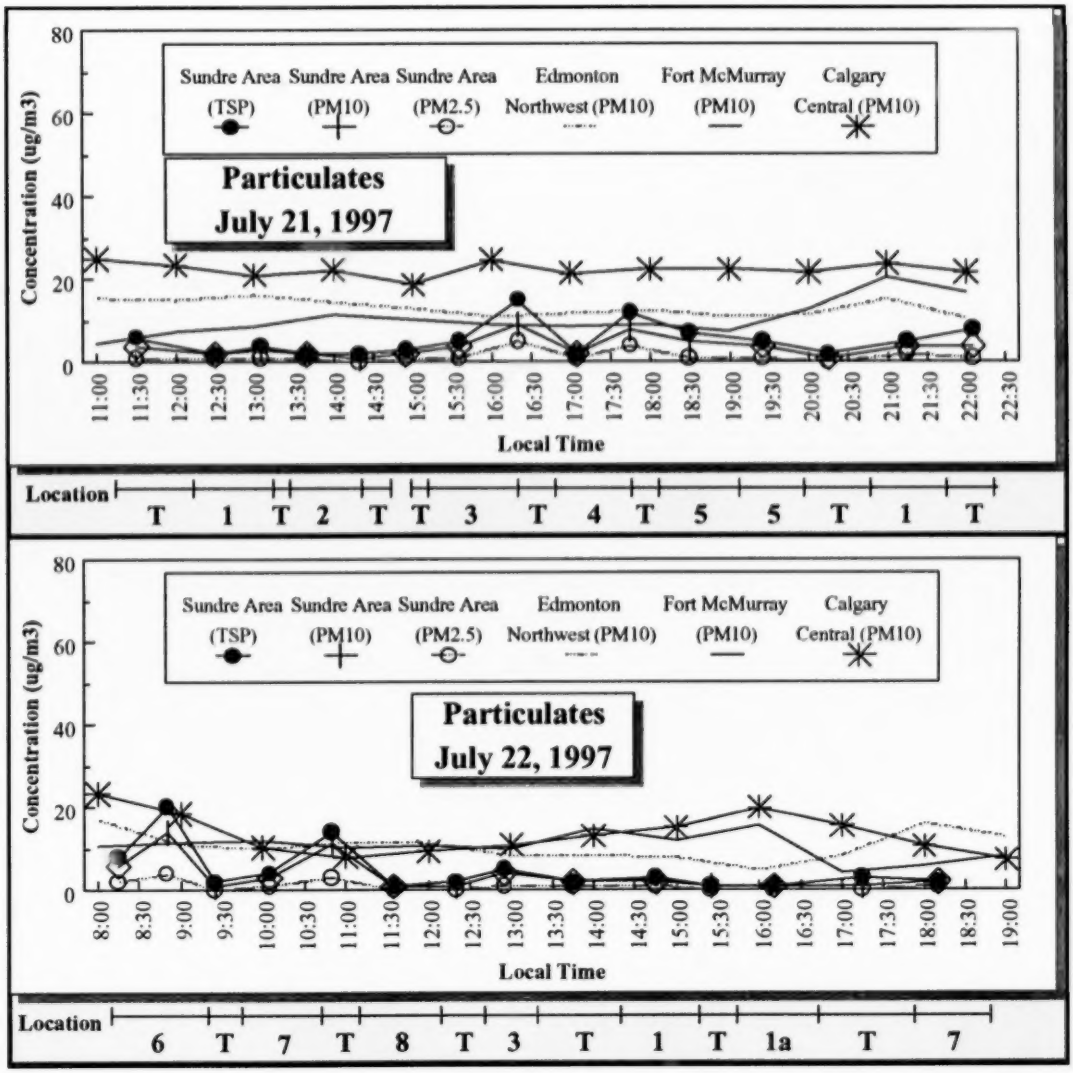
Average Hydrogen Sulphide and Total Reduced Sulphur Concentrations in the Caroline/Sundre Area


Sundre Area
Sundre Area (TRS)
Calgary East
Edmonton East
Fort McMurray
Fort Saskatchewan
One-Hour Guideline for Hydrogen Sulphide
Hydrogen Sulphide July 21, 1997
Concentration (ppm)
Local Time
Location
T 1 T 2 T T 3 T 4 T 5 5 T 1 T
Hydrogen Sulphide July 22, 1997
T 6 T 7 T 8 T 3 T 1 T 1a T 7
Hydrogen Sulphide July 23, 1997
T 6 T 10 T 11 T T

Location Legend	
Symbol	Location Description
1	Range Rd 4-02 1 mile south of Township Rd 32-00 (Bergen Rd) (between Shell Shantz and Mobil Harmattan facilities))
2	Hwy 22 and Township Rd 32-00 (Bergen Rd) (1 mile northwest of Mobil Harmattan Gas Plant)
3	Hwy 22 between Township Rd 34-00 and 34-02 (0.5 miles west of the Amoco tank farm)
4	Burnstick Lake Rd. at equivalent of Rge Rd 6-02 & Twp rd 35-02 (2.5 miles northwest of the Shell Caroline gas plant)
5	Well site roads approx 0.5 miles northwest of the Shell Caroline gas plant
6	Range Rd 5-03 0.5 miles north of Township Rd 34-00 (near Amoco Battery)
7	Township Rd 34-04(Hwy 587) 0.25 to 1.25 miles west of Rge Rd 6-01 (1.5 miles SSW of Shell Caroline gas plant)
8	Well lease Rd approx 3.5 miles SSW of Shell Caroline gas plant
9	Shell Caroline gas plant access road approx 0.5 miles ENE of plant
10	Range Rd 4-05 and Township Rd 34-02A (1 mile SSW of Amoco South Caroline gas plant)
11	Well lease Rd about 1 mile SW of Shell Caroline gas plant

Summer, 1997

Average Particulate Concentrations in the Caroline/Sundre Area


Sundre Area (TSP)
Sundre Area (PM10)
Sundre Area (PM2.5)
Edmonton Northwest (PM10)
Fort McMurray (PM10)
Calgary Central (PM10)
Particulates July 21, 1997
Concentration (ug/m3)
Local Time
Location
T 1 T 2 T T 3 T 4 T 5 5 T 1 T
Particulates July 22, 1997
6 T 7 T 8 T 3 T 1 T 1a T 7

Location Legend	
Symbol	Location Description
1	Range Rd 4-02 1 mile south of Township Rd 32-00 (Bergen Rd) (between Shell Shantz and Mobil Harmattan facilities))
2	Hwy 22 and Township Rd 32-00 (Bergen Rd) (1 mile northwest of Mobil Harmattan Gas Plant)
3	Hwy 22 between Township Rd 34-00 and 34-02 (0.5 miles west of the Amoco tank farm)
4	Burnstick Lake Rd. at equivalent of Rge Rd 6-02 & Twp rd 35-02 (2.5 miles northwest of the Shell Caroline gas plant)
5	Well site roads approx 0.5 miles northwest of the Shell Caroline gas plant
6	Range Rd 5-03 0.5 miles north of Township Rd 34-00 (near Amoco Battery)
7	Township Rd 34-04(Hwy 587) 0.25 to 1.25 miles west of Rge Rd 6-01 (1.5 miles SSW of Shell Caroline gas plant)
8	Well lease Rd approx 3.5 miles SSW of Shell Caroline gas plant
9	Shell Caroline gas plant access road approx 0.5 miles ENE of plant
10	Range Rd 4-05 and Township Rd 34-02A (1 mile SSW of Amoco South Caroline gas plant)
11	Well lease Rd about 1 mile SW of Shell Caroline gas plant